double periodicity, with the magnetization lost from one layer transferred to its neighbour (Fig. 1).

Their discovery immediately raises many interesting questions and challenges. For example, it will be important to verify this remarkable effect in experiments other than neutron reflectometry. Such a large variation in magnetic moment should be accompanied by a rearrangement of electronic states over a relatively large energy scale, and therefore should be detectable by experiments such as photoemission spectroscopy. Furthermore, the absence of a pronounced anomaly in the magnetization data around the superconducting temperature, where this modulation sets in, implies the existence of a sum rule where the total magnetic moment is strictly conserved. It is hard to believe that such an effect is accidental, and there must be some interesting physics behind this observation.

The million-dollar question is, of course, how such a startling change on a scale of tens of nanometres arises through an interfacial coupling of superconductivity and ferromagnetism. Hoppler and colleagues[1] suggest that a not unusual competition between different electronic phases might play an important part in this extreme sensitivity to external perturbation. Indeed, the perovskite manganese oxides are widely known as a prototypical system for such competition between different phases. But could such a competition between two phases also occur in the high-T_c cuprate used in this study, where the superconducting temperature is already lower than in related compounds that do not contain praseodymium? And given that the ferromagnetic compound used here has a large magnetic moment, what is the part played by macroscopic electromagnetic interactions in this ferromagnet when placed next to a superconductor? Clearly, much remains to be explored in these exciting new systems. ❐

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NANOMEDICINE

Veni, vidi, vici and then... vanished

Non-toxicity in multifunctional inorganic nanoparticles is rare. However, with careful engineering of silicon-based nanoparticles they can be used *in vivo* as imaging and drug-delivery agents and later degraded and cleared without toxic effects.

Victor S.-Y. Lin

In contrast to the rapidly increasing use of nanoparticles in industrial products and processes, their use for drug delivery and biomedical implants is still in its infancy. Part of this slow take-off can be ascribed to the health risks associated with introducing new materials into our own bodies. The administration of these materials to humans has to be preceded by a long series of pre-clinical and clinical tests[1], and critical issues such as biodistribution, circulation, immune response, toxicity, sedimentation and clearance need to be scrutinized[2]. On page 331 of this issue, Sailor and co-workers[3] report how porous silicon nanoparticles can be used as both imaging and drug-delivery agents *in vivo*. They demonstrate a key feature of these nanoparticles: the ability to disintegrate slowly in aqueous solution and thereby be cleared from an organism.

Inorganic nanoparticles are usually considered as species with high structural stability. The stability is vital to ensure that the particles do not prematurely decompose and release their valuable (and perhaps dangerous) payload on the way to the targeted tissue, a risk that is often associated with organic nanoparticles. On the other hand, the extremely high stability can be a serious problem once their tasks are completed, as solid particles can accumulate in tissues, leading to other complications over time. It is necessary, therefore, to reach equilibrium between structural stability and degradability. Such a trade-off seems to be achieved by the silicon nanoparticles presented here.

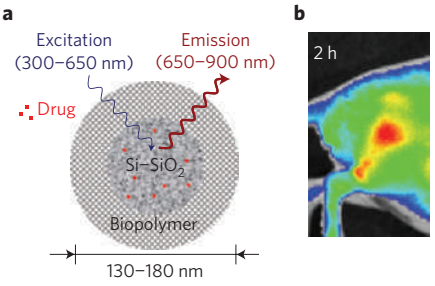

Figure 1 | Nanoparticle structure and accumulation in mouse tumours. **a**, Schematic of the structure and the infrared luminescence from polymer-coated silicon/silica nanoparticles. **b**, Imaging of infrared fluorescence from dextran-covered nanoparticles around two hours after their injection into a mouse. The nanoparticle accumulation in the mouse's tumour (seen as red) is clear.

Nanomaterials are typically prepared by one of two approaches: 'top-down', for example when nanolithography is used; or 'bottom-up', such as in self-assembly processes. Sailor and co-workers[3] prepare silicon nanoparticles in a way that could be considered a combination of both of these approaches. They electrochemically etch the surface of a single-crystal silicon wafer to produce a flake of porous silicon and break it down further to smaller particles by ultrasonication. Filtration of the resulting suspension leads to particles under 200 nm in size. The authors then incubate the particles in water, allowing a layer of silica to grow on the surface of the nanoparticles. The localized defects that result at the interface between the surface silica and the underlying silicon, as well as the creation of a quantum confinement effect, make the particles luminescent, as previously described by the research groups of Sailor[4] and Hayne[5] (Fig. 1a).

Porous nanoparticles are very a promising platform for drug delivery, as these materials can transport large

amounts of poorly soluble drugs and keep their activity intact by hiding them inside the pores[6]. Sailor and colleagues load the anticancer drug doxorubicin into the silicon nanoparticles, and demonstrate its slow release under physiological conditions. Although the particles themselves show no cytotoxicity towards a culture of cancer cells, the doxorubicin-loaded nanoparticles are perfectly capable of inducing cell death.

Interestingly, the process that produces the activation of luminescence in the nanoparticles is also the origin of the ability of these particles to be effectively degraded in aqueous solution. The defects between the silica and silicon are easily hydrolyzed and have a key role in the degradation process. The authors propose that the degradation product is orthosilicic acid, which is known to be readily eliminated in urine[7]. When mice are intravenously injected with suspensions of the nanoparticles, they are able to clear them in a matter of weeks. The mice continue to gain weight in the same way as mice injected only with saline solution. No significant toxicity that could be related to the degradation product of the material was observed in the animal tissues.

Sailor and colleagues also demonstrate how the particles can be used for *in vivo* imaging by intramuscular and subcutaneous injections of nude mice with suspensions of the nanoparticles. They follow injected particles by monitoring their near-infrared fluorescence. Although the intravenous injection of the nanoparticles into mice gives signals lower than desired because of rapid degradation of the material, the adsorption of a dextran layer onto the surface of the particles increases the stability of the material, allowing better and longer-lasting visualization. Furthermore, injection of the dextran-covered material into nude mice bearing a tumour leads to an accumulation of the nanoparticles in the tumour, aiding its visualization (Fig. 1b).

One can envisage that future generations of these inorganic nanoparticle-based delivery systems would be able to protect precious pharmaceutical or nutriceutical cargos of enzymes, DNA and RNA against harsh environments, such as highly acidic gastric juice for various gastro- and intestinal-delivery applications. The key challenge would be to design the structure and surface properties of these solid nanomaterials to control the timing and degree of drug release and thus ensure that the local concentration reaches the therapeutic levels needed.

The beauty of nanotechnology resides in its promise that materials can be manipulated or controlled at the level of individual atoms[8]. Given the size of nanoparticles, and the possibility of incorporating different functionalities into their surfaces, it is reasonable to expect them to perform tasks at the subcellular scale. Such tasks might well be carried out in whole organisms, as long as safety is guaranteed. The work by Sailor and collaborators[3] is a promising showcase for the application of inorganic nanoparticles for drug delivery and imaging in humans in the near future. ❐

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SUPERCONDUCTIVITY

Commonalities in phase and mode

Muon and neutron experiments on the new FeAs-based superconductors reveal phase diagrams and spin excitation modes with striking similarities to a wide range of other unconventional superconductors.

Yasutomo J. Uemura

Superconducting systems continue to challenge physicists and materials scientists interested in understanding the mechanisms of electron pairing and condensation, which lie at the origin of superconductivity itself. Since the 1980s several novel systems have been discovered, including the high-transition-temperature (T_c) cuprates and the alkali-doped buckyball superconductors. More recently, the discovery of a La(O,F)FeAs superconductor[1] at the beginning of 2008 triggered a burst of studies, leading to several hundred reports on FeAs-based systems within a year. As many of these new superconductors show behaviours that are different from those of conventional ones — as explained by the Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity in 1957 (ref. 2) — it seems obvious to look for comparisons and classification among a wide range of unconventional superconductors.

When a new superconducting system is discovered, determination of the phase diagram represents a starting point for further investigation and is therefore one of the first goals for experimentalists. In particular, because most of the newly discovered superconductors have 'parent' compounds — the undoped and non-superconducting versions of the materials — that show antiferromagnetic (AF) order, understanding the details of how the transition from the AF to the superconducting (SC) state occurs with increasing doping concentration can provide essential information. Muon spin relaxation (μSR) and neutron scattering are two strong particle probes obtained at accelerator or reactor facilities. These two probes detect magnetism in real (muons) and momentum (neutrons) space and provide a wide range of information on both static and dynamic magnetic behaviours even without the application of external magnetic fields.

On pages 305 and 310 of this issue, two research groups using μSR report their findings in RE(O,F)FeAs (RE = rare earth) with RE = La (ref. 3) and Sm (ref. 4). Together with the earlier neutron study on RE = Ce (ref. 5), these represent the first sets of phase diagrams of the so-called '1111' FeAs-based superconductor family. As seen in Fig. 1a, the results, although still showing differences in the details, indicate that the SC state literally takes over the AF state. In the RE = La system, Luetkens *et al.*[3] found an abrupt disappearance of the AF state, accompanied by an orthorhombic structural distortion. In the RE = Sm system, Drew *et al.*[4] found the AF and SC regions to be coexistent, which may have been due to phase separation. In the RE = Sm case, further experimental studies with higher-quality specimens will be necessary to rule out extrinsic effects of possible spatial spread or heterogeneity of dopant concentrations.